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Upgrades to the M-PERC and PERC Models to Improve Short Term Tropical Cyclone Intensity Forecasts

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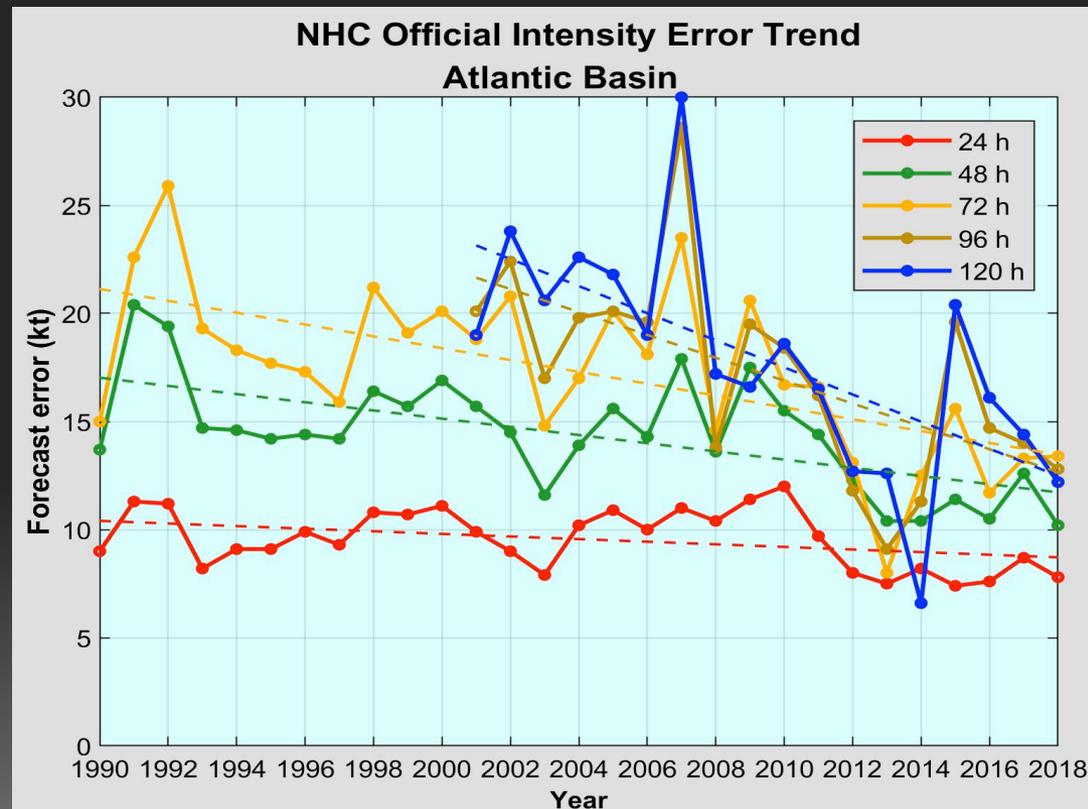
Radar image of Hurricane Maria approaching Puerto Rico courtesy of Brian McNoldy *Univ. of Miami, Rosenstiel School*)

Goal – Make incremental improvements to short range forecasts by giving forecasters a tool that objectively identifies Eyewall Replacement Cycle (ERC) onset.

Microwave Probability of Eyewall Replacement (M-PERC) model

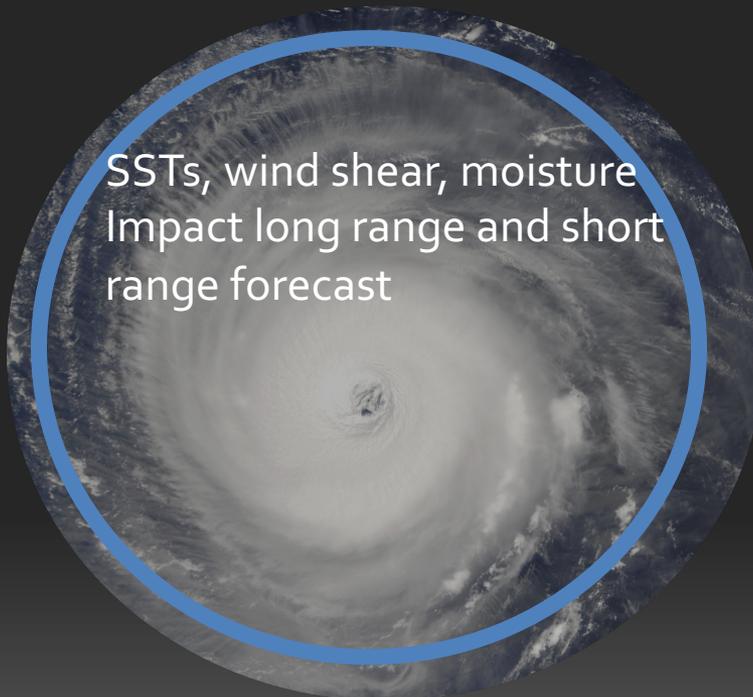
Existing microwave-based model
M-PERC was developed using Atlantic data

- Baseline existing Atl-based model
- Create Eastern/Central Pacific data
- Create new model based on this basin-specific data
- Test model in near real-time
- Update web-based display to add SHIPS environment parameters (shear, sst, etc)

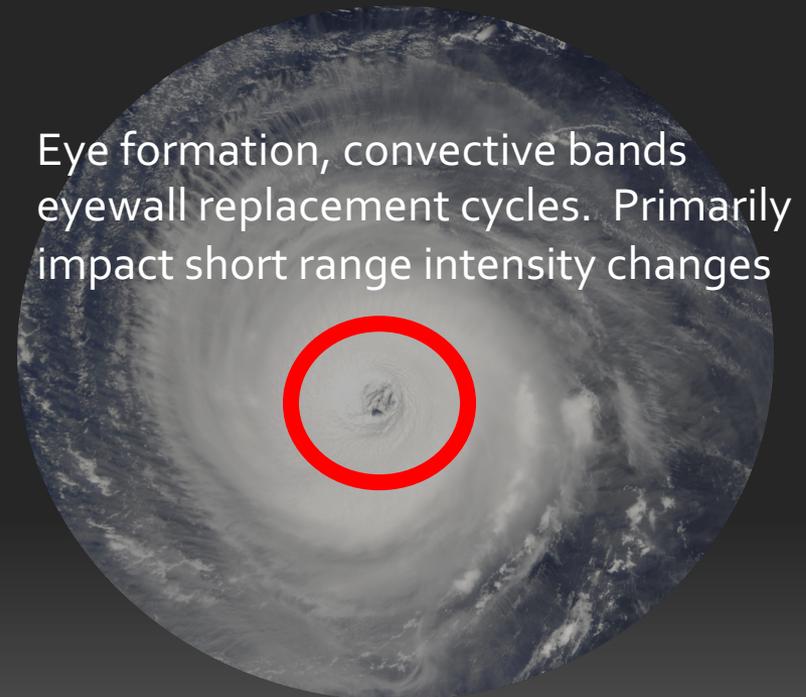


TC Intensification

Environmental Controls



Internal Controls



“The disparity between SHIPS forecasts and the observed intensity changes during ERCs is strongly suggestive that the typical environmental controls of intensity change, on which SHIPS is largely based, are temporarily **countermanded** while dynamic processes internal to the storm dominate the intensity evolution.”- Kossin



ERC Onset Guidance: M-PERC



In 2018 alone NHC mentioned ERCs 36 times in forecast discussions.

HURRICANE MATTHEW DISCUSSION NUMBER 12 NWS NATIONAL HURRICANE CENTER MIAMI FL AL142016 1100 PM EDT FRI SEP 30 2016. **Matthew probably is near its peak intensity and will likely maintain a similar strength during the next 12 hours or so. Data from the reconnaissance plane show an incipient outer band of maximum winds, indicating that an eyewall replacement cycle could occur soon.** This should result in fluctuations in intensity, and given that southwesterly shear is still affecting the cyclone, some weakening is anticipated.

ERC forecast tools available to forecasters currently

E-SHIPS – ERC adjustments to SHIPS forecast when ERC onset is known

PERC – Probability of ERC (based on environment, Vmax and infrared satellite information)

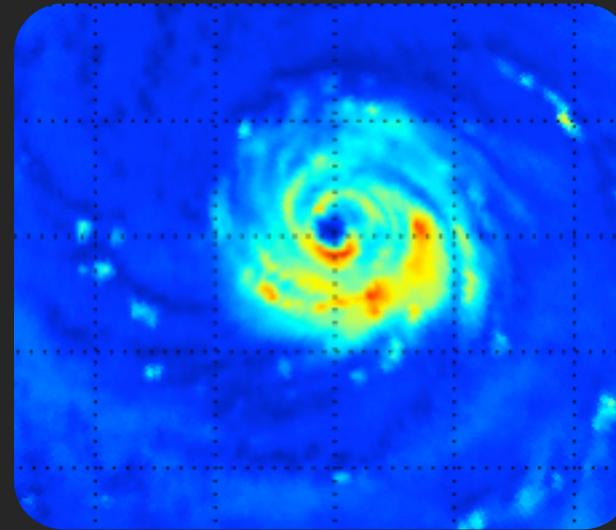
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** PROBLTY OF AT LEAST 1 SCNDRY EYEWL FORMTN EVENT AL142016 MATTHEW 10/01/2016 00 UTC **
TIME(HR) 0-12 12-24(0-24) 24-36(0-36) 36-48(0-48)
CLIMO(%) 48 43( 70) 28( 79) 23( 84) <-- PROB BASED ON INTENSITY ONLY
PROB(%) 47 51( 74) 92( 98) 97(100) PC4 UNAVAIL...MODEL SKILL DEGRADED
  
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** DSHIPS INTENSITY FORECAST ADJUSTED RELATIVE TO ONSET OF ERC WEAKENING PHASE **
TIME (HR) 0 6 12 18 24 36 48 60 72 84 96 108 120
>24HR AGO (DSHIPS) 135 136 128 117 108 101 102 107 104 67 71 69 72
18HR AGO 135 134 126 115 106 99 100 105 102 65 69 67 70
12HR AGO 135 132 131 120 111 104 105 110 107 70 74 72 75
6HR AGO 135 129 126 125 116 109 110 115 112 75 79 77 80
NOW 135 126 120 117 116 109 110 115 112 75 79 77 80
IN 6HR 135 136 127 121 118 115 116 121 118 81 85 83 86
IN 12HR 135 136 128 119 113 109 110 115 112 75 79 77 80
  
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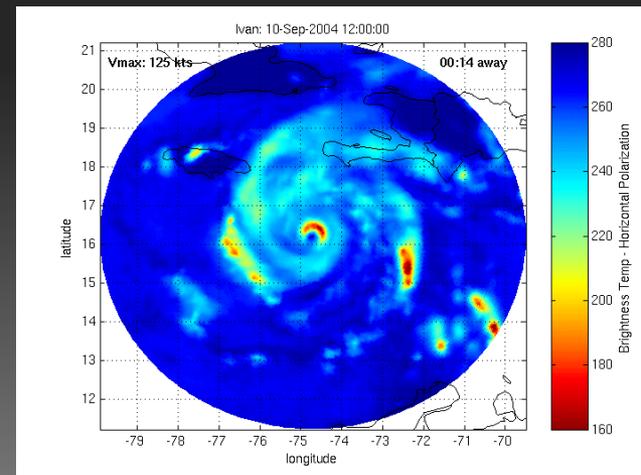
Secondary Eyewall Formation (SEF) – A nearly continuous spiral band that wraps more than 50% around an existing eyewall



Eyewall Replacement (ERC) – The complete process of the replacement of the inner eyewall by an outer eyewall

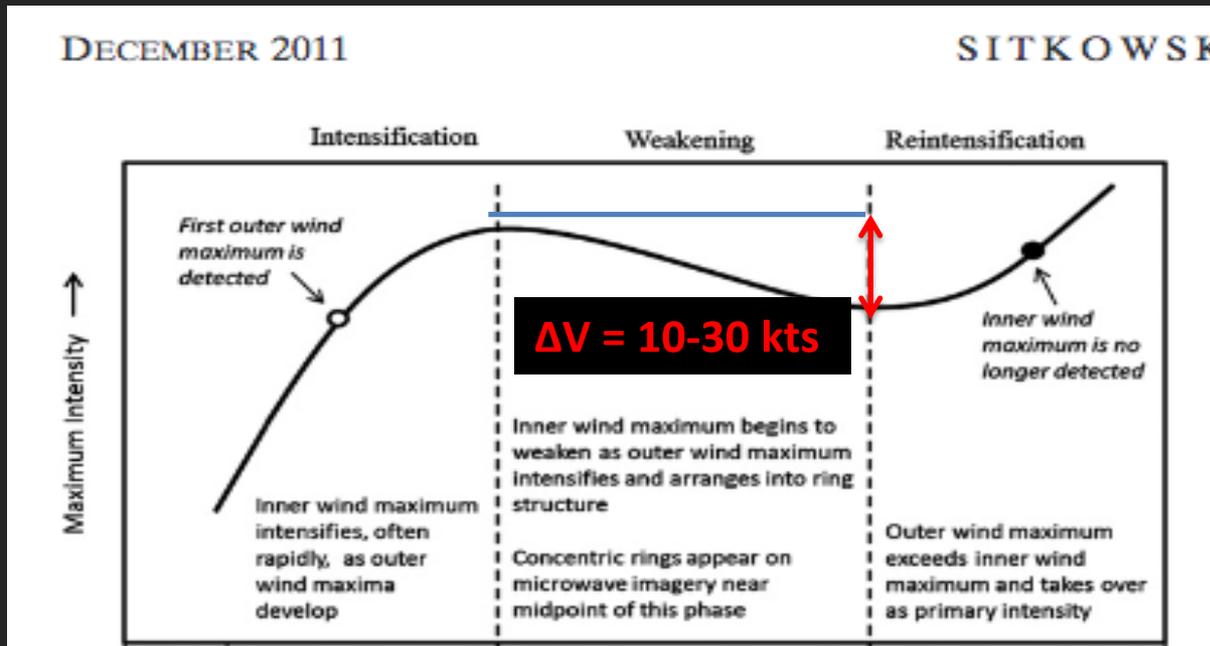
Secondary wind maxima can be observed by aircraft and radar velocity data.

In the absence of these sources microwave imagery can be used as a proxy

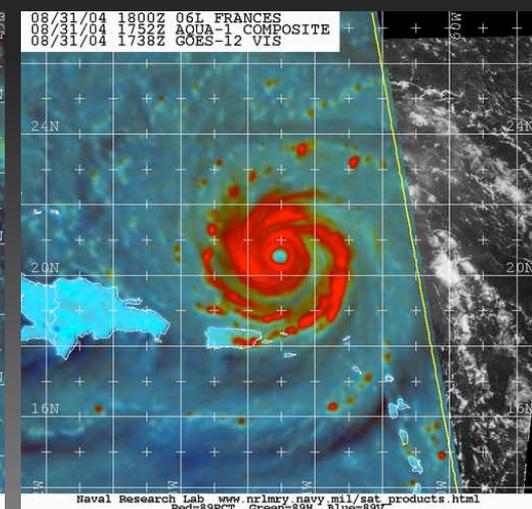
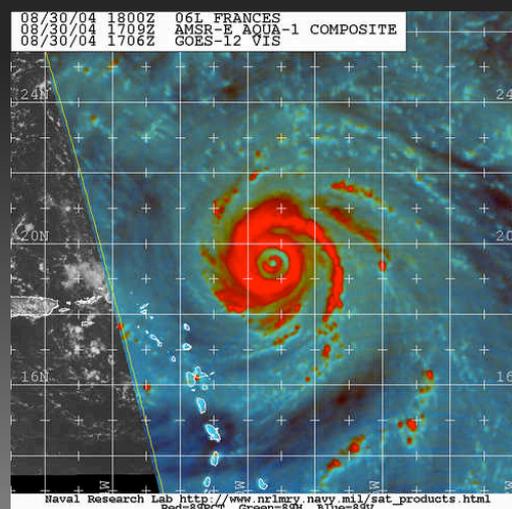
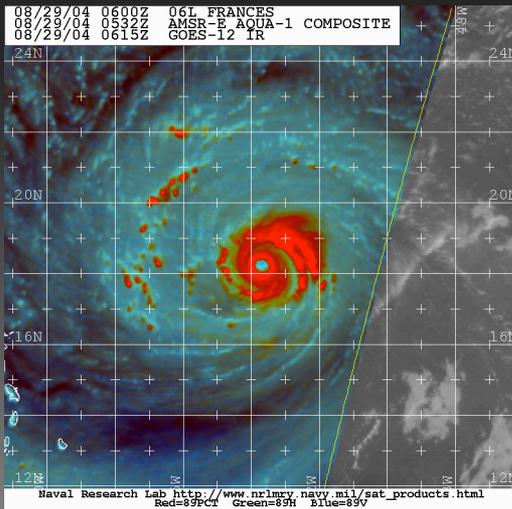




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Sitkowski, M., J. P. Kossin, and C. M. Rozoff, 2011: Intensity and structure changes during hurricane eyewall replacement cycles. *Mon. Wea. Rev.*, **139**, 3829-3847.





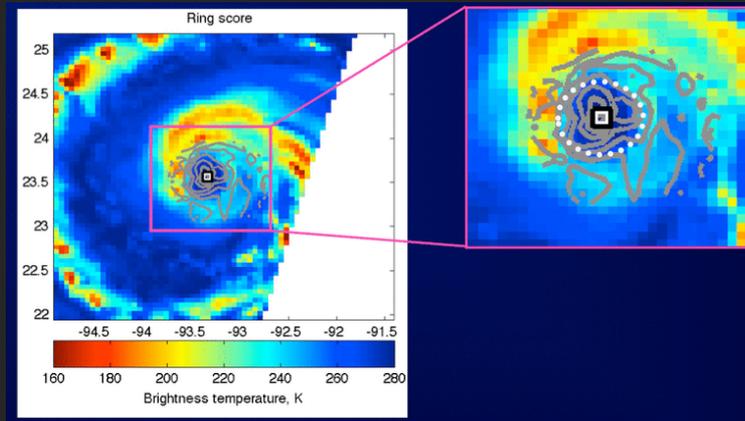
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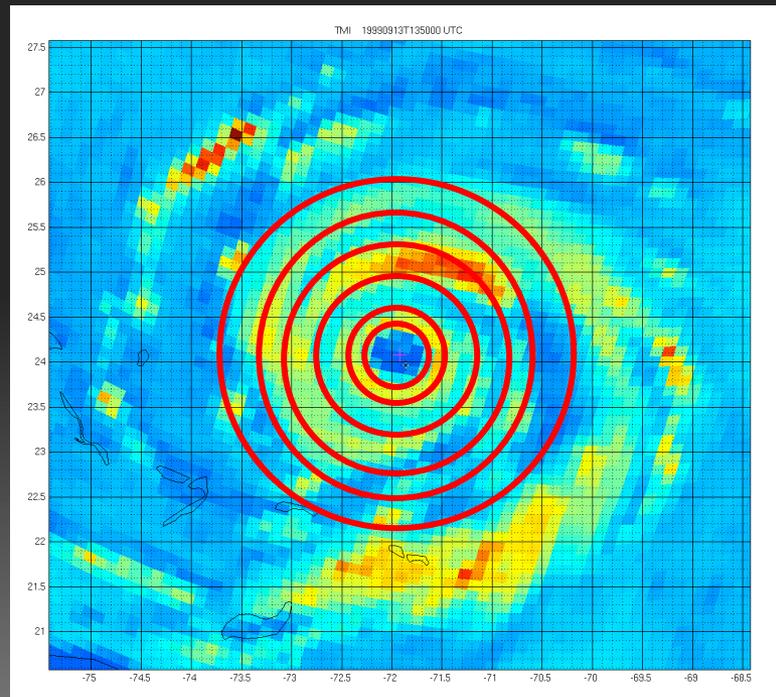


M-PERC starts with Automated Rotational Center Hurricane Eye Retrieval (ARCHER)

Fixes TC position using 89 GHz imagery



Ring score is computed for all pixels thus the ring score can be used to determine primary and secondary ring “candidates”

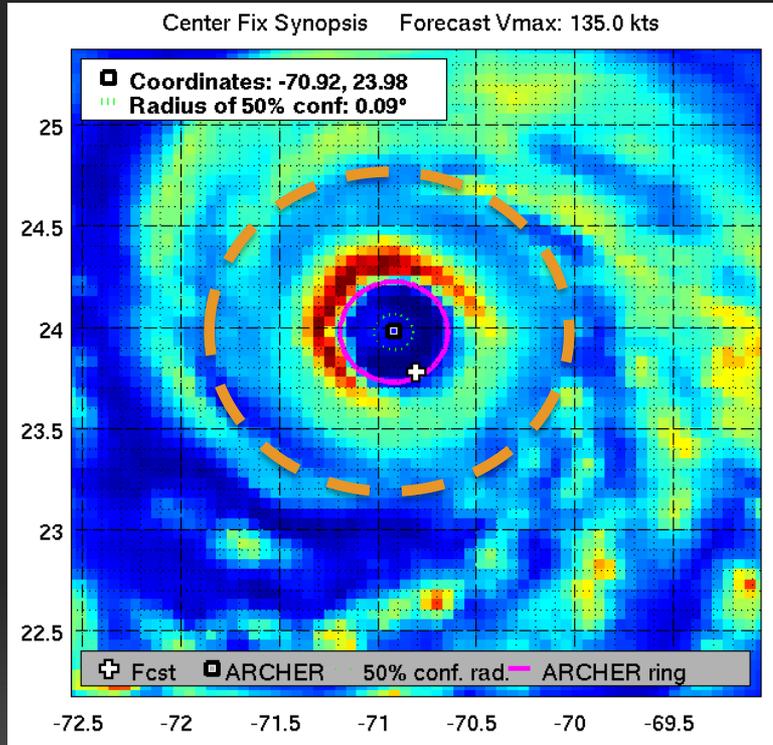




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Ring scores can be displayed in hovemuller form to show time and space evolution of the features.



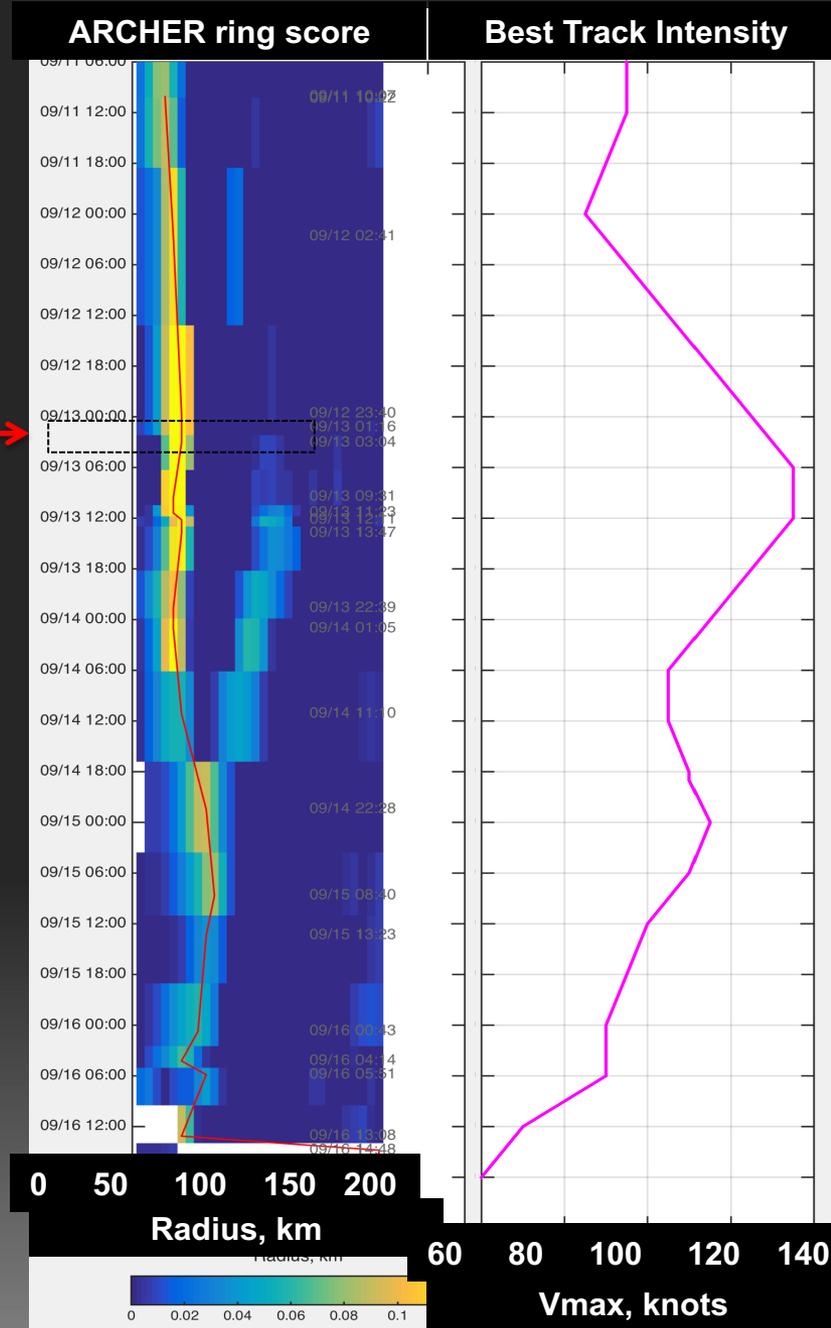
9/12

9/13

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*ARCHER ring score plotted versus time shows a branching/merging pattern during ERCs



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Ring score profiles from 2 storms.

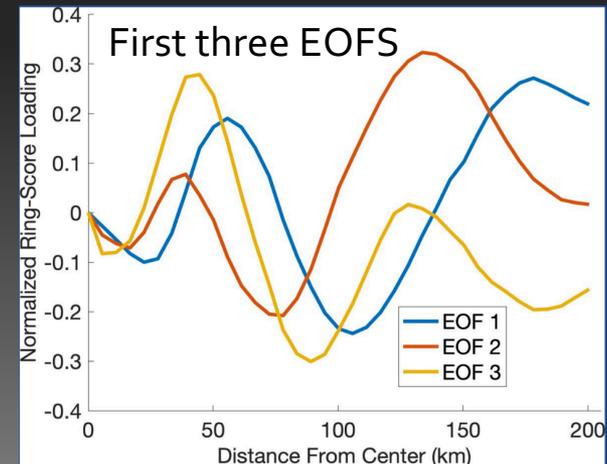
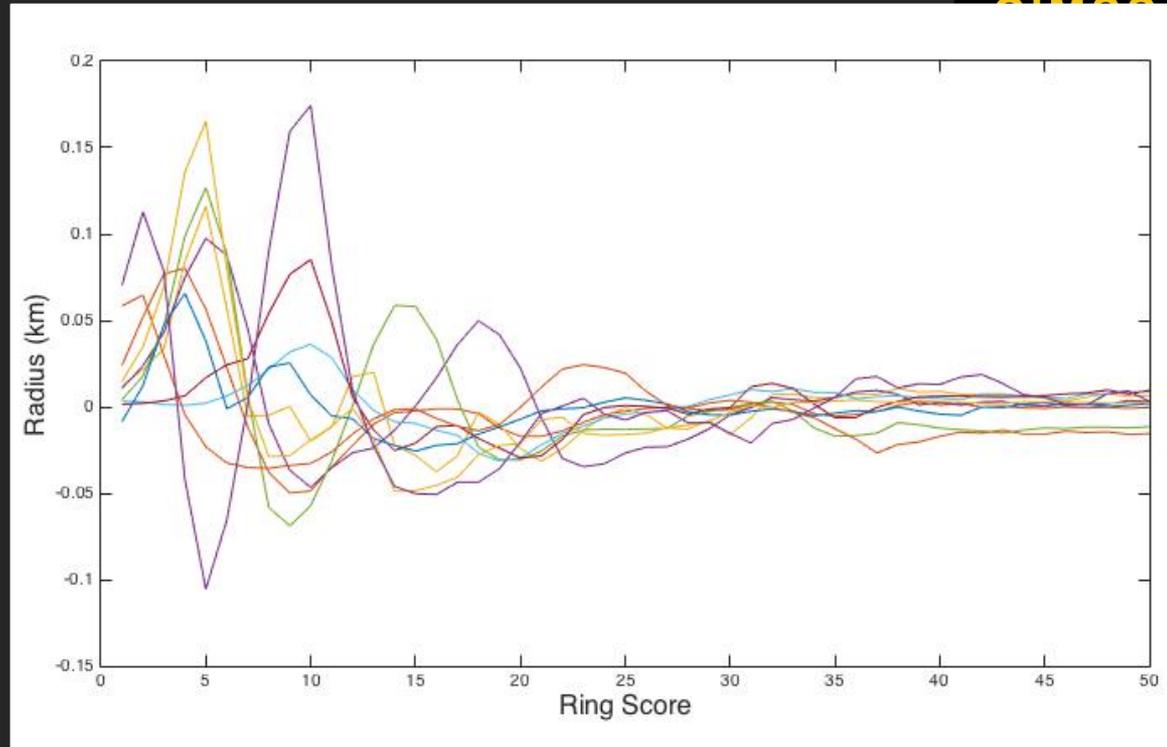
M-PERC Model

PCA on 1787 profiles from storms 1999-2011 to develop logistic regression predictors

Change in PCs over 6,12 ,18 and 24 hours added to set of predictors. Vmax and delta-Vmax also are used for a total of 18 predictors.

Two models are developed. Full model will all predictors and a Vmax-only model to provide some measure of comparison of the impacts of the microwave data

Model output does not start until best track Vmax > 65 knots





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Web page output for M-PERC
On CIMSS ARCHER page

Training Data 1999-2011 -> 41 storms with
84 ERC events

Verification

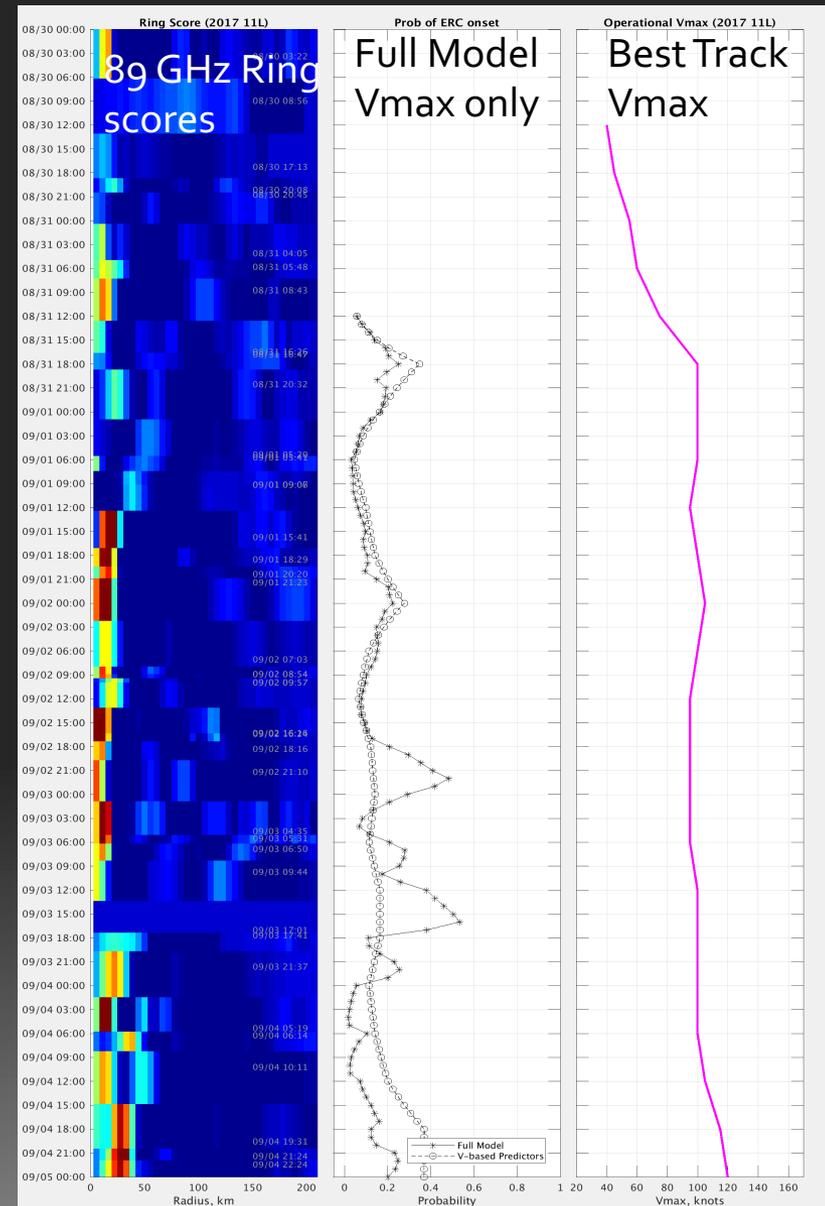
Verification data 2012-2019 -> 22 storms with
48 events

Evaluate performance of existing model in Atlantic

Using prob of >25% 37 hits and 11 misses
Using prob of >50% 22 hits and 24 misses

BSS for the sample (climatology of 13%) is 32%

Average delta-Vmax following SEF is -13 knots
Average forecast intensification was +4 knots





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Though M-PERC runs for all storms globally the model was developed using Atlantic data

Model is sensitive to radial distribution of the banding features. These features exhibit variability that has a basin dependence. IE storms tend to be smaller in the Eastern Pacific and larger in the Western Pacific than Atlantic storms.

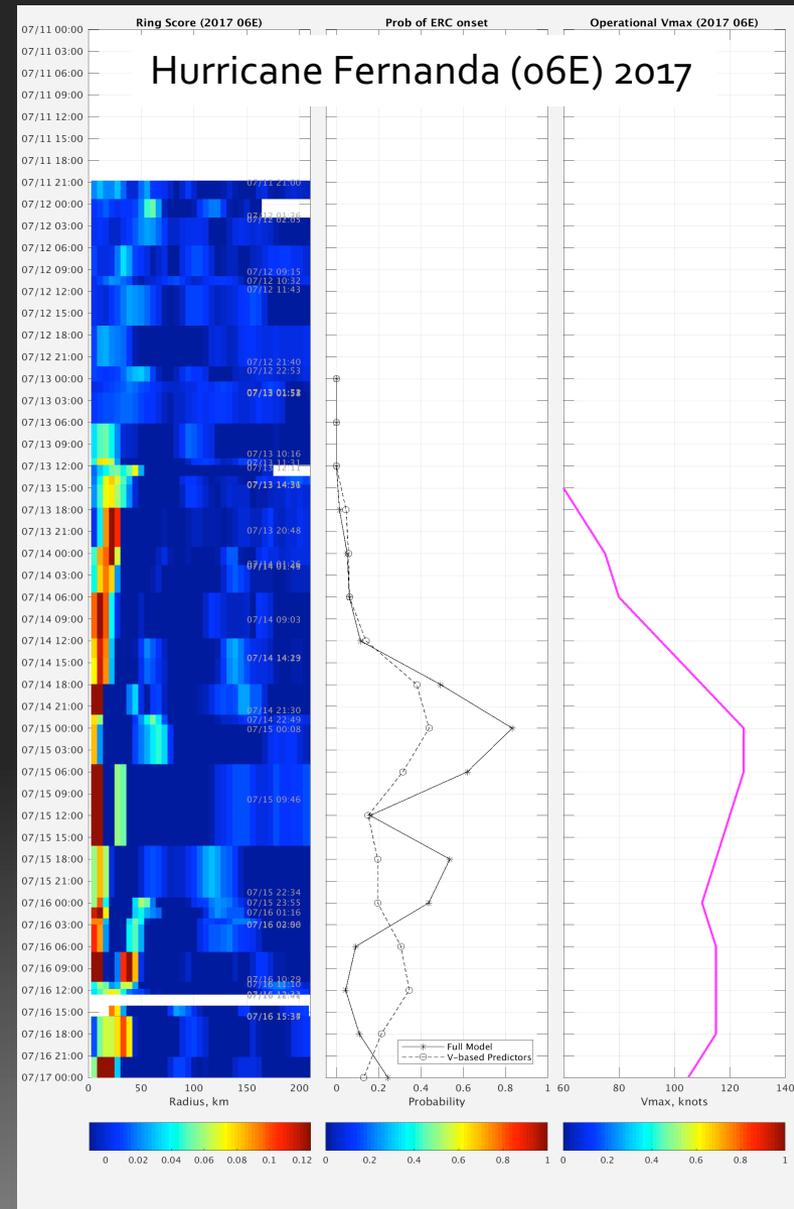
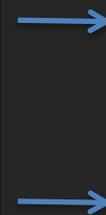
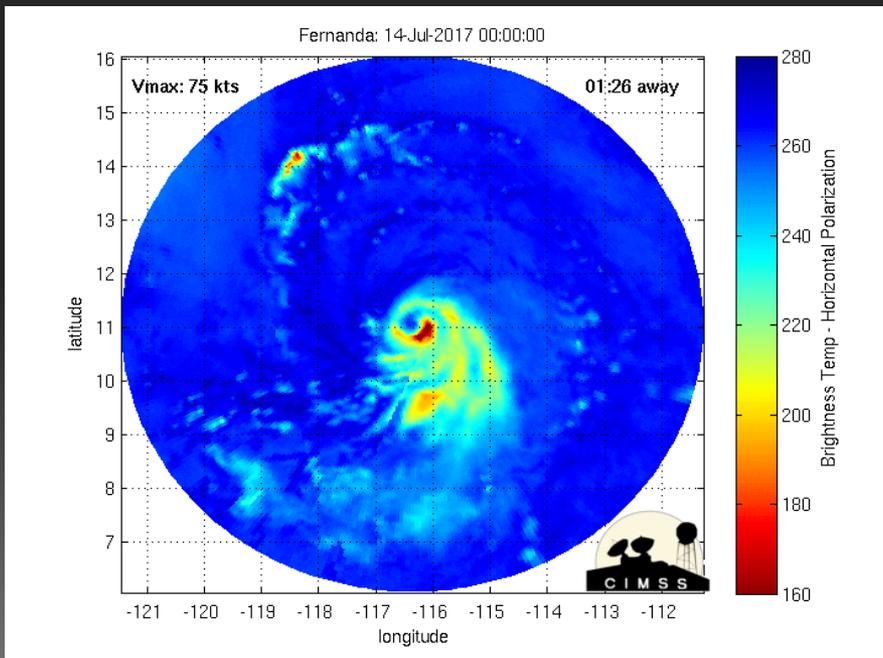
Verify model performance in EPAC to test this potential size dependence

Develop EPAC version of M-PERC.

Create three models: Vmax-only, microwave-only and full model to better evaluate contribution of the various terms.

ERC Onset Guidance: M-PERC

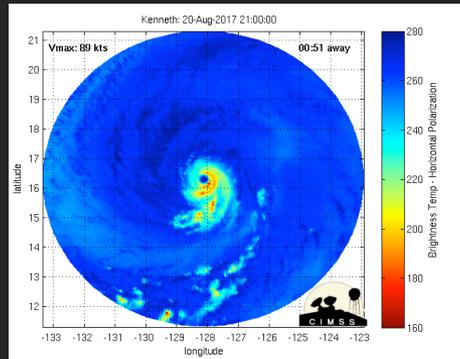
EPAC Example for Hurricane Fernanda
Reasonable performance, storm is similar
in size to Atlantic training data.



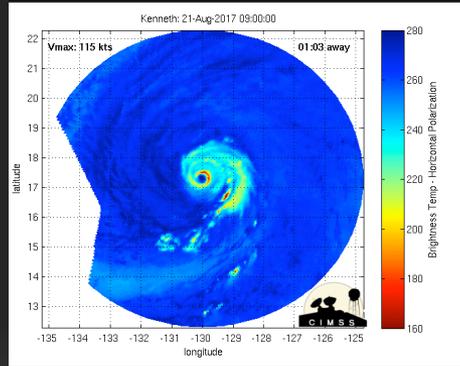
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ERC process can aid in RW

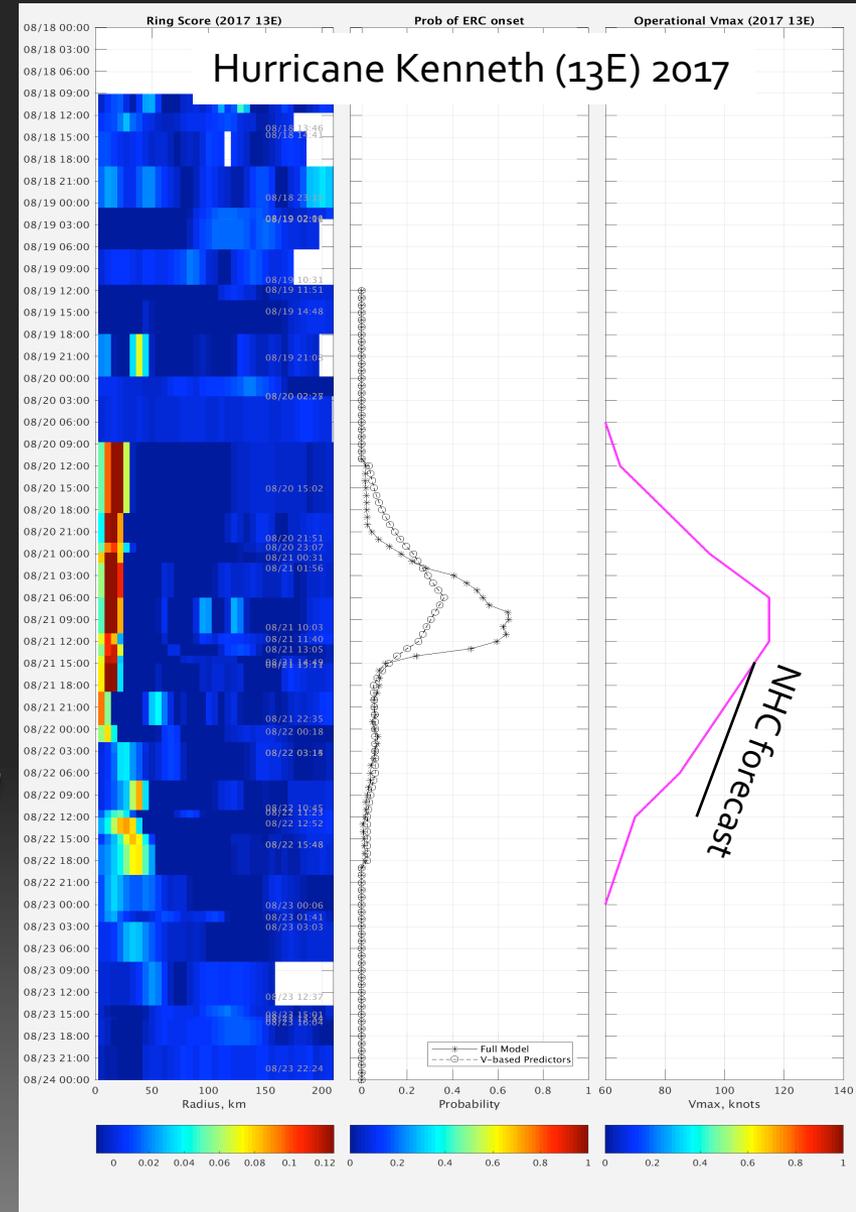
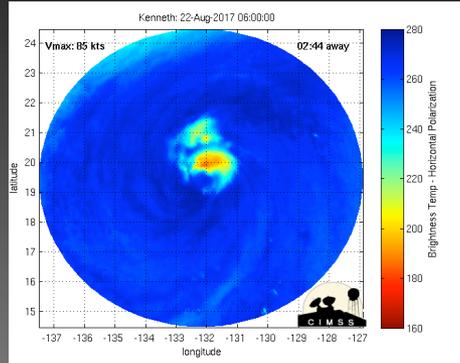
SEF development



SEF development
Erosion in NW quad



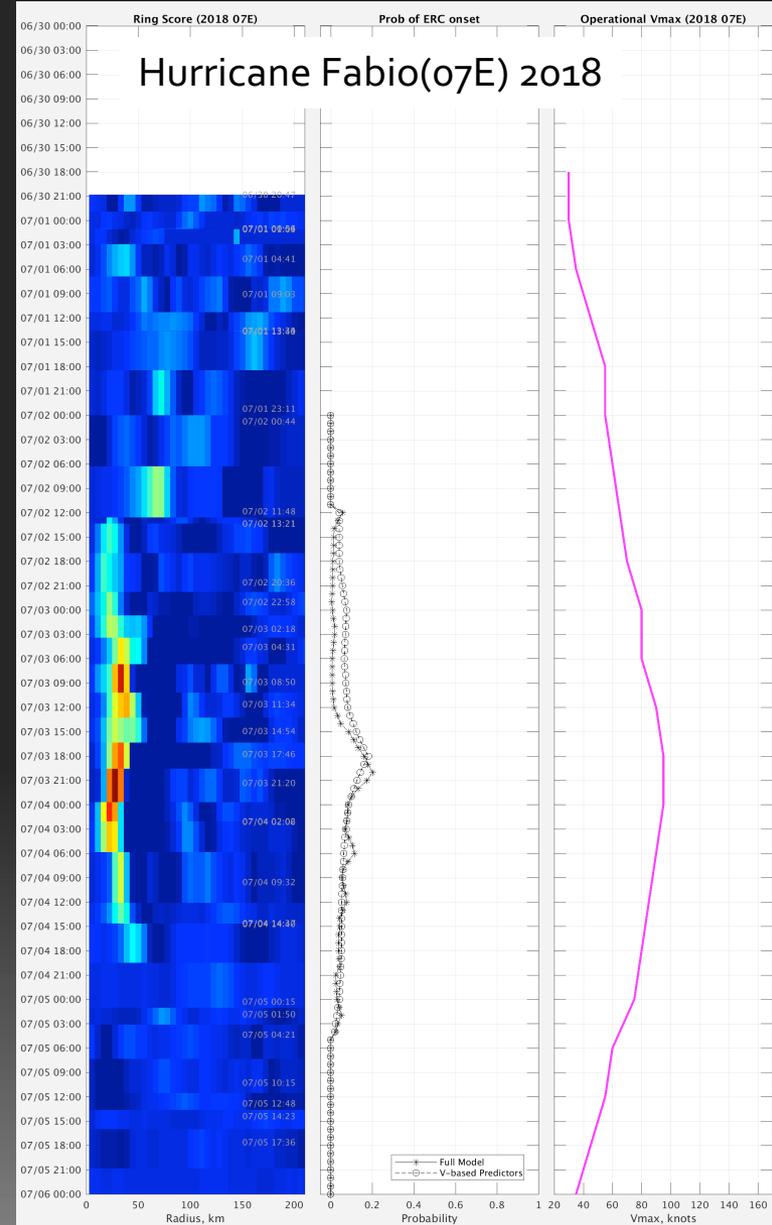
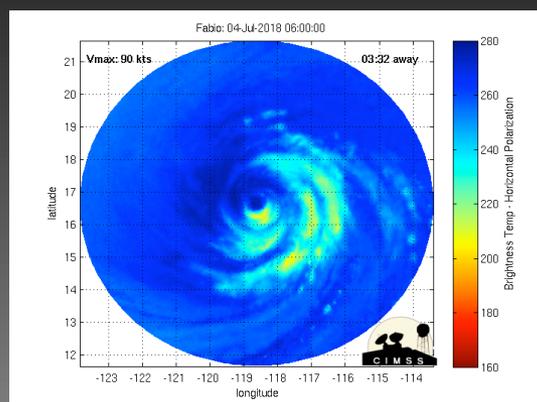
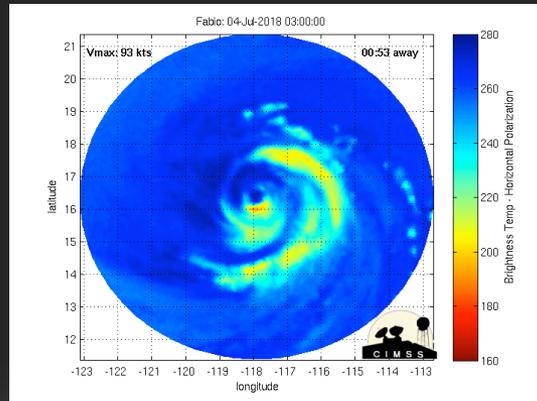
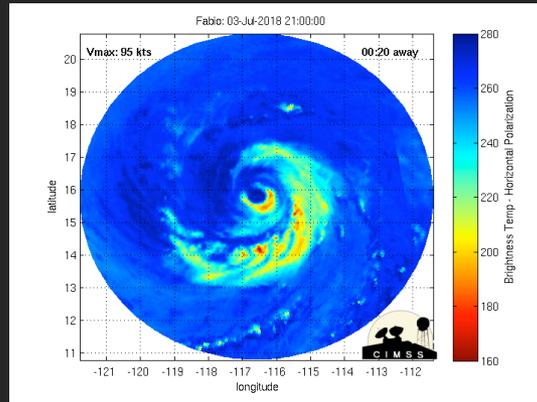
Entrainment of stable air into inner core interrupts ERC process. Core rapidly weakens



ERC Onset Guidance: M-PERC

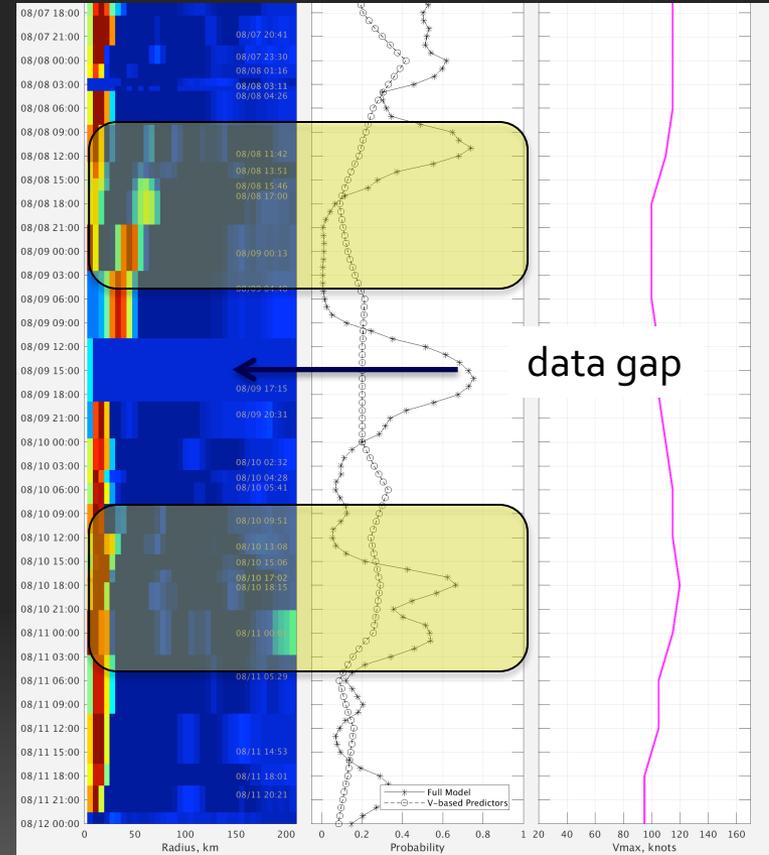
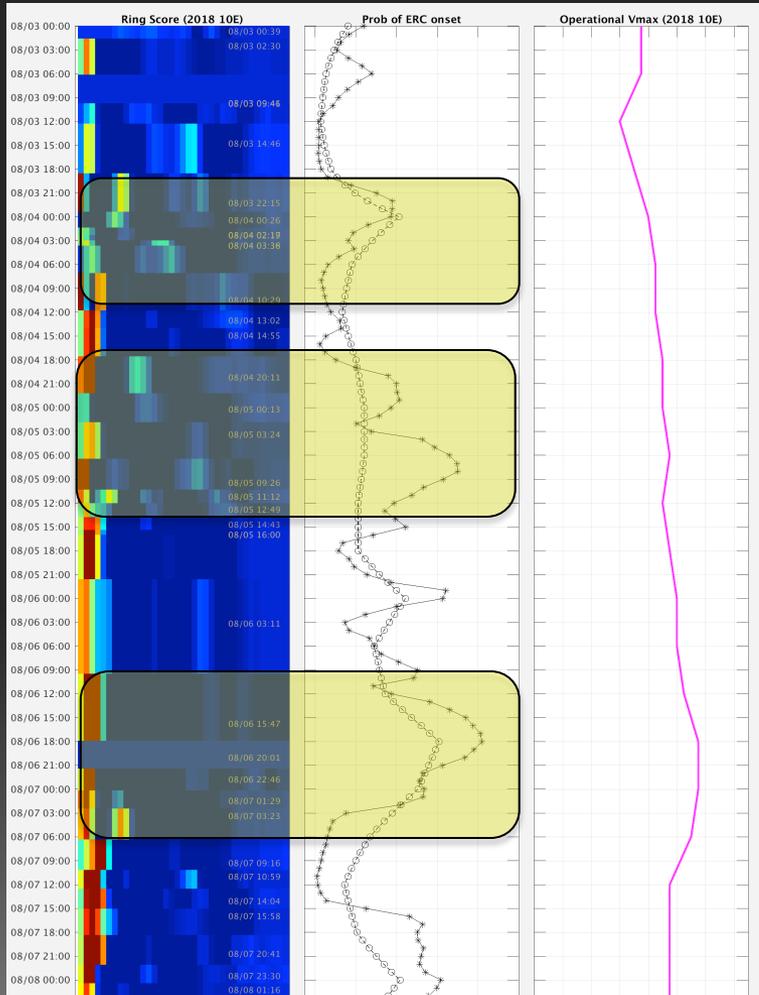
EPAC miss. Vmax is low compared to sample ERC events.

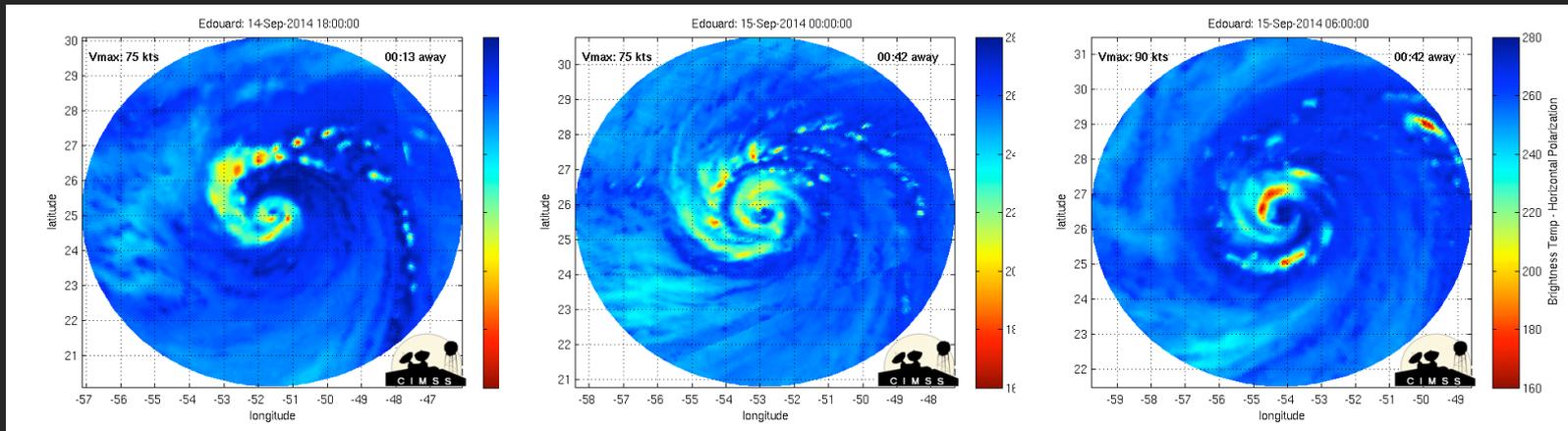
Microwave-only model might help with these cases



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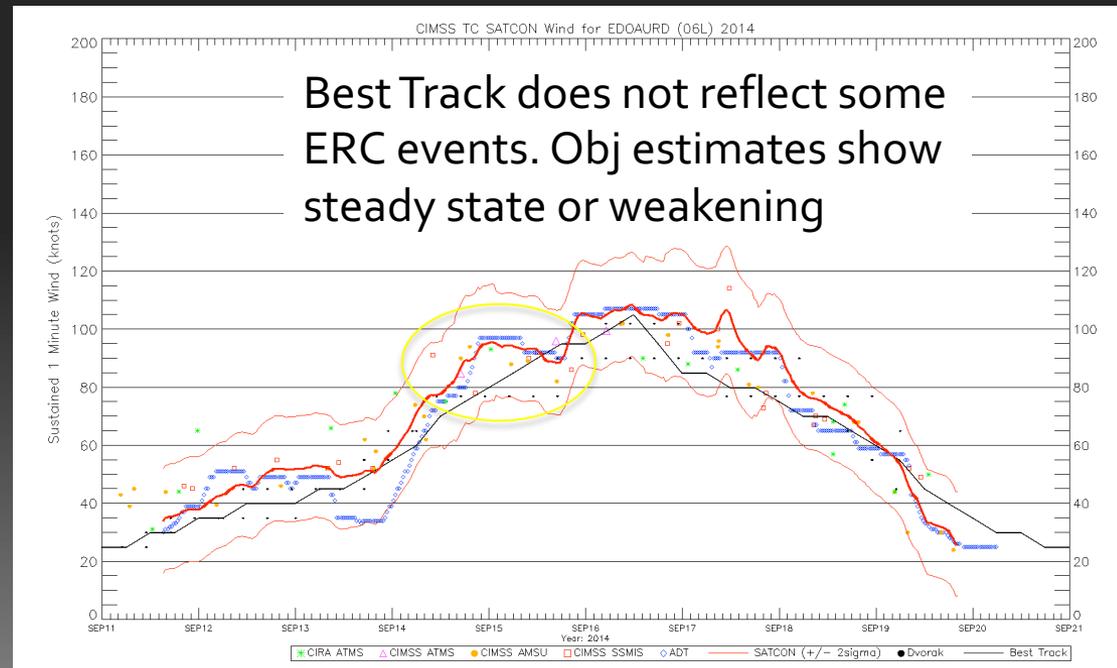
Hurricane Hector (10E) 2018 five ERC events





Hurricane Edoard 2014

Many such cases exist in various best tracks (all basins). This impacts LMI, RI and RW data





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M-PERC captures the majority of ERC events with lead time that can assist in intensity forecast decision process. In EPAC 22 hits for 27 events with 1 F/A using prob $> 25\%$. Hits = 16 for prob $> 50\%$

Moving Forward

Continue to identify EPAC/CPAC cases back to 1999

Develop new M-PERC model using basin-specific data. Compare results with Atlantic-based model to highlight differences if any.

Update web display to include wind shear, OHC and other environment parameters that impact ERC to allow forecasters to see if process will continue or possibly be disrupted.